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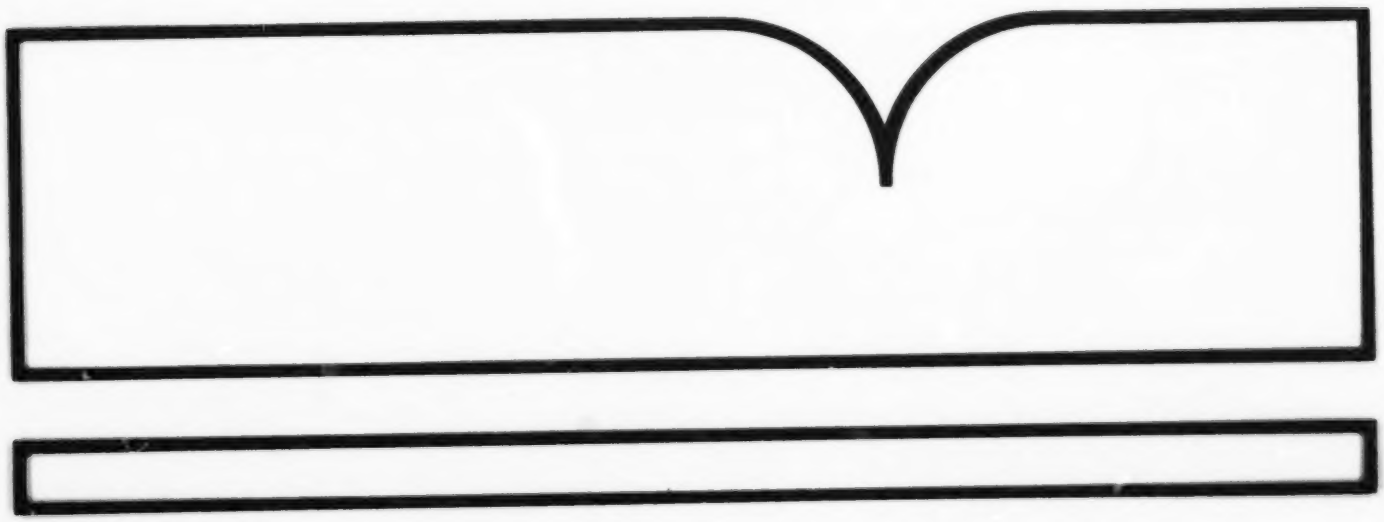

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Summary of Risk Assessment Methodologies for Municipal Sludge Reuse or Disposal Options

Randall J.F. Bruins
Larry Fradkin
Jerry F. Stara, D.V.M., Ph.D.
Environmental Criteria and Assessment Office
U.S. Environmental Protection Agency
Cincinnati, Ohio

ABSTRACT

Risk assessment methods have been developed which can be used to calculate criteria for controlling toxic pollutants in municipal wastewater sludges. These methods consist of algorithms, ranging from simple to complex, which allow calculation of exposure and risk from various sludge disposal practices. These calculations may show a need for management practice controls or for numerical limits on specific pollutants. Criteria for land-applied or distributed and marketed (D&M) sludge may take the form of application rate limits (kg/ha) or concentration limits, calculated to control pollutant levels in the food chain or off-site movement in air or water. Criteria for landfilled sludge are defined in terms of acceptable leachate concentrations, as determined by an appropriate leachate characterization test, to prevent excessive groundwater contamination or vapor emission. Incineration criteria are expressed as limitations on stack emission rates (g/sec), based on predicted air concentrations at ground level. Criteria for sludge which is ocean-disposed at the 106-Mile Site are calculated in terms of sludge concentration and total daily pollutant input to the site, in order to protect marine life and human consumers of seafood. These risk assessment methods were developed in a research environment in order to promote scientific consistency in the regulatory process.

INTRODUCTION

The Environmental Criteria and Assessment Office of the U.S. EPA Office of Research and Development in Cincinnati, Ohio, has recently developed risk assessment methodologies which can be used to calculate criteria for protecting human health and the environment from toxic pollutants in municipal wastewater sludges [1-4]. Since municipal sludges are managed utilizing a number of different reuse or disposal practices, separate assessment methods were developed to address land application (including distribution and marketing [D&M]), landfilling, land-based incineration, and ocean disposal of sludges. Each methodology provides procedures for estimating the fate and transport of sludge-borne pollutants and for evaluating the potential for effects on humans or other organisms. The methods also describe data requirements for using these procedures to calculate criteria. The criteria are not necessarily numerical in all cases. In some instances, the risk assessment calculations can be used to determine appropriate controls on the design or operation of the management practice which achieve the same level of environmental protection. Such management controls are often preferred for their practicality. In many cases, however, the methodologies suggest that numerical limits on pollutant levels in the sludge should be calculated.

The risk assessment methodologies for each practice describe algorithms that can be used to calculate whether or not adverse effects would be expected from a given sludge constituent under a given set of conditions. Separate algorithms are presented for different pathways of potential exposure. For example, the methodology for sludge landfilling develops separate algorithms for contaminant movement to groundwater and for volatilization through the soil cap. The algorithms range from simple to complex. For example, in order to prevent phytotoxicity, the land application methodology states that soil levels toxic to plants should be determined from the literature for each chemical, and that sludge applications should be limited to prevent the occurrence of such levels. Minimal calculation is required. On the other hand, the algorithm for the groundwater pathway for sludge landfilling requires the use of three computer models in succession to determine the effects of unsaturated zone transport, geochemical equilibria, and saturated zone transport, respectively, on potential for human exposure.

Using these procedures, conditions can be established which would prevent adverse effects. As mentioned previously, these conditions ("criteria") may consist of a set of recommendations for design or operation of the practice. For example, a maximum ground slope or minimum depth to groundwater could be

recommended for land application practices in order to prevent surface or groundwater pollution, respectively. Often, however, numerical criteria which limit the chemicals themselves are derived. Depending on the algorithm, these numerical criteria may take the form of chemical concentrations in the sludge (on a dry or wet weight basis), rates of disposal (in terms of chemical mass disposed per unit area or per unit time or both), or some other form. The form of criteria dictated by each algorithm will be described for each reuse/disposal practice.

LAND APPLICATION (INCLUDING D&M)

Municipal sludges may be used to enhance productivity of agricultural or forest lands, to reclaim severely disturbed lands or may be applied to land which is dedicated to sludge disposal. Sludge may also be sold or given away in bag or bulk form to private or institutional users, a practice referred to as distribution and marketing (D&M). These practices combined accounted for about 42 percent of municipal sludge disposal in the U.S. in 1980 [5].

There are a wide variety of pathways by which chemicals in land-applied sludge can impact humans or other organisms. Human exposure potential is greatest when sludge is applied to agricultural lands or provided to the public for lawn or garden use. Uses on other lands pose less exposure potential initially, but in many cases the possibility exists of land-use conversion to agricultural or residential use.

Plant uptake of sludge-applied chemicals has been shown to increase as a function of amount of chemical applied. Criteria to protect humans or animals consuming these plants therefore will usually be expressed in terms of chemical mass applied per unit area, or kg/ha. For chemicals, such as many metals, which are not appreciably lost over time, the mass refers to the cumulative amount applied; no further additions would be permitted once the limit was reached. For chemicals that are lost through degradation or other processes, criteria are expressed as areal application per year, or kg/ha/yr. The criterion is the amount which could be reapplied annually without ever exceeding a maximum cumulative amount.

In some situations, humans or animals may consume the sludge directly. Grazing animals may be directly exposed to surface-applied sludge which is not incorporated into the soil. Similarly, children are known to ingest soil and could be exposed to pure sludge. For these types of exposures, the dry-weight pollutant concentration in the sludge is more pertinent than the pollutant application rate.

Offsite movement of sludge-borne chemicals can also occur through transport in surface runoff or by percolation to groundwater. These movements are treated as a function of annual areal pollutant application rate, rather than sludge concentration. Air concentrations resulting from volatilization may be a function of sludge concentration (wet weight) immediately upon application, but long-term average concentrations would again be a function of the annual areal application rate.

LANDFILLING

Approximately 15 percent of municipal sludge disposal in 1980 was by landfilling [5]. Most landfilled sludge is codisposed with municipal solid waste, while a lesser (undetermined) amount is disposed in sludge-only landfills, or monofills. The risk assessment methodology for landfilling [2] considers only the monofilling practice; codisposal will be dealt with in a separate assessment effort. It is assumed that site design features such as runon/runoff controls are adequate to protect local surface waters and that the daily application of cover material prevents any problems of windblown dust. Numerical criteria are suggested to prevent hazard from groundwater contamination: design criteria are not recommended since very few sludge landfills have liners and these liners may rupture. Numerical criteria are also suggested in order to limit the vapor concentrations downwind from the site.

Contaminant movement to groundwater and subsequent movement to a point of human use are predicted using a succession of transport and geochemical-equilibrium models. The required input to the first model (unsaturated zone transport) is a leachate concentration. In addition to leachate concentration, the total mass in the landfill of each pollutant must be estimated in order to determine the maximum length of time over which a leachate of a given concentration could be produced, since this duration can affect the predicted maximum concentration at the point of use.

Downwind movement of vaporized contaminant is estimated using a Gaussian air dispersion model. The vapor concentration immediately above the source during daily (uncovered) operation, or post-closure, is estimated from the leachate concentration using Henry's Law. Thus the leachate concentration is required for both of these transport pathways.

The procedure currently recommended by the U.S. EPA for the classification of solid wastes, the Toxicity Characteristic Leachate Procedure (TCLP) [6], is also recommended to be used with sludges for reasons of consistency. However, the adequacy of the TCLP for sludge leachate characterization purposes is presently being investigated by the U.S. EPA's Office of Water.

Chemicals to be analyzed in the leachate or whole sludge, as determined by preliminary screening procedures, could include various metals, cyanide, nitrate, nitrosamines, chlorinated hydrocarbon pesticides, PCB and phthalate esters [7, 8].

INCINERATION

Incineration accounted for about 27 percent of sludge disposal in 1980 [5]. Incineration technologies in use include primarily the multiple hearth and fluidized bed furnace types. The risk assessment methodology for sludge incineration [3] examines potential risk to humans from incinerator stack emissions. Contaminant concentrations at ground level near the facility are estimated by the use of air dispersion models which account for aerodynamic downwash (resulting from low stack heights) as well as local terrain and meteorology. The required input to the model is the stack emission rate of the contaminant, in g/sec.

Contaminants likely to be of concern vary according to incinerator type. Metals are more likely to pose a problem at the higher temperatures typical of fluidized bed furnaces. Loss of volatile organics from the upper hearths and incomplete destruction of other organics are likely to be more prevalent for multiple hearth furnaces. Classes of organics possibly requiring criteria include chlorinated hydrocarbon pesticides, polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH) and phthalate esters [7, 8].

OCEAN DISPOSAL

Ocean disposal of municipal sludge by barging is currently permitted in only one location, the newly designated 106-Mile Ocean Waste Dump Site off the New York/New Jersey coast [9]. Ocean disposal in 1980 (at the previously designated "12-Mile Site") accounted for about 4 percent of U.S. sludge disposal [5].

The risk assessment methodology for ocean disposal of sludge is concerned with both protection of marine life near the site and protection of humans consuming seafood from that area. Water-column concentrations to which marine organisms are exposed are estimated from dispersion models. To calculate short-term concentrations within the dump site itself, where toxic effects on marine organisms are most likely, the sludge concentration (wet weight), as well as speed, dumping rate and positioning of barges, is the required input information. To estimate long-term, down-range concentrations, which are of more importance for assessing human exposure, only the total contaminant input to the dump site on a daily basis is required. Methods are not yet available to estimate sedimentation rates for sludge particles and potential for seafloor accumulation at the 106-Mile Site.

Chemicals potentially requiring analysis include metals, chlorinated hydrocarbon pesticides, PCB, PAH, phthalate esters and aromatic amines [7,8]. In addition to analysis of individual constituents, whole-sludge bioassay methods may be used to determine the degree of dilution required to prevent aquatic toxicity. While not dealt with in these risk assessment methodologies, which focus on evaluating hazards of individual chemicals, these bioassay methods have been required for ocean-disposed wastes under other authorities [10], and are also useful for sewage sludge.

PATHOGENS

The U.S. EPA is currently reevaluating the existing, technology-based pathogen regulations, which define Processes to Significantly Reduce Pathogens (PSRP) and Processes to Further Reduce Pathogens (PFRP) [11]. A feasibility study for performing risk assessments for pathogens was completed in 1985 [12, 13]. Based on the feasibility study, the U.S. EPA plans to develop risk assessment methodologies for pathogens (i.e., bacteria, viruses, protozoa, helminths and fungi) in the future. Such methodologies would enable the Agency to better determine the efficacy of the technology-based approach, or could indicate that a concentration-based approach, as used for chemicals, would be more appropriate.

CONCLUSION

The development of these risk assessment methodologies for chemical pollutants was undertaken by the Office of Research and Development prior to, and separate from, the criteria derivation effort itself. Criteria derivation involves the collection of data on specific chemicals to use as inputs to the methodology. The latter effort has been

undertaken by the Office of Water Regulations and Standards in Washington, D.C., in connection with regulation development. The segregation of methodology development from the regulatory process enabled more attention to be given to consistency among the approaches for the various reuse/disposal options, rather than the traditional medium-by-medium approach. Separation also enabled a more objective scientific peer review process, focused on refining methods rather than results.

In spite of their development in a research environment, however, these methodologies contain many assumptions, judgments and uncertainties due to the limitations of scientific knowledge. Their utility in regulatory development depends upon the careful selection of input data and an accurate understanding of the strengths and limitations of the results.

REFERENCES

[1] U.S. EPA, "Development of Risk Assessment Methodology for Land Application and Distribution and Marketing of Municipal Sludge," ECAO-CIN-489, Environmental Criteria and Assessment Office, Cincinnati, Ohio, April, 1986.

[2] U.S. EPA, "Development of Risk Assessment Methodology for Municipal Sludge Landfilling," ECAO-CIN-485, Environmental Criteria and Assessment Office, Cincinnati, Ohio, March, 1986.

[3] U.S. EPA, "Development of Risk Assessment Methodology for Municipal Sludge Incineration," ECAO-CIN-486, Environmental Criteria and Assessment Office, Cincinnati, Ohio, April, 1986.

[4] U.S. EPA, "Development of Risk Assessment Methodology for Ocean Disposal of Municipal Sludge," ECAO-CIN-492, Environmental Criteria and Assessment Office, Cincinnati, Ohio, April, 1986.

[5] U.S. EPA, "Process Design Manual for Land Application of Municipal Sludge," EPA-625/1-83-016, Municipal Environmental Research Laboratory, Cincinnati, Ohio, Oct., 1983. p. 1-2.

[6] Federal Register, Vol. 51, No. 114, June 13, 1986. pp. 21648-21693.

[7] U.S. EPA, "Summary of Environmental Profiles and Hazard Indicies for Constituents of Municipal Sludge: Methods and Results," Office of Water Regulations and Standards, Washington, D.C., July, 1985.

[8] Lomnitz, E., Bruins, R. and Fradkin, L. Biocycle, Vol. 26, No. 7, Oct., 1985, pp. 52-54.

[9] Federal Register, Vol. 49, No. 88, May 4, 1984, pp. 19005-19012.

[10] Code of Federal Regulations, Title 40, Part 227, July 1, 1985, pp. 155-168.

[11] Code of Federal Regulations, Title 40, Part 257, July 1, 1985, pp. 341-342.

[12] Fradkin, L., Lutkenhoff, S., Stara, J., Lomnitz, E., and Cornaby, B. JWPCF, Vol. 55, No. 2, December, 1985, pp. 1036-1039.

[13] U.S. EPA, "Pathogen Risk Assessment Feasibility Study", Environmental Criteria and Assessment Office, Cincinnati, Ohio and Office of Water Regulations and Standards, Washington, D.C., Nov., 1985.